The Air Microwave Yield (AMY) experiment to measure the GHz emission fom air shower plasma

- Gabriella Cataldi (for the AMY collaboration)
  - The collaboration
  - The physics case
  - The AMY experiment
  - Simulation
  - First Test Beam @ BTF
  - Improvement of the experimental apparatus
  - Second Test Beam @ BTF
  - Conclusions

The Collaboration and the experiment aim

AMY CSN-V financed for 2 years 2011-2012

- **Roma ToV** C. Di Giulio, G. R. Fernandez, **G. Salina, V. Verzi**
- **Lecce** G. Cataldi, M. R. Coluccia, P. Creti, I. De Mitri, D. Martello, L. Perrone
- **Aquila** M. Iarlori, S. Petrera, V. Rizi
- Genova: R. Pesce
- Frascati: B. Bonomo, L. Foggetta, G. Mazzitelli
- Prague: M. Bohacova
- Chicago: P. Facal, M. Monasor, P. Privitera, C. Williams
- Santiago: J. A. Muniz
- Madrid: J. R. Vazquez
- IPNO: F. Salamida
- LPNHE: M. Blanco, R. Gaior, A. Letessier-Selvon
- LPSC K.: Louedec, S. Le Coz, F. Montanet
- Siegen: M. Settimo
- Karlsruhe: R. Engel, M. Riegel, R. Smida, F. Werner

The aim is to make a precise measurement of the MBR power and frequency spectrum repeating a test similar to a previous measurement

The physics case

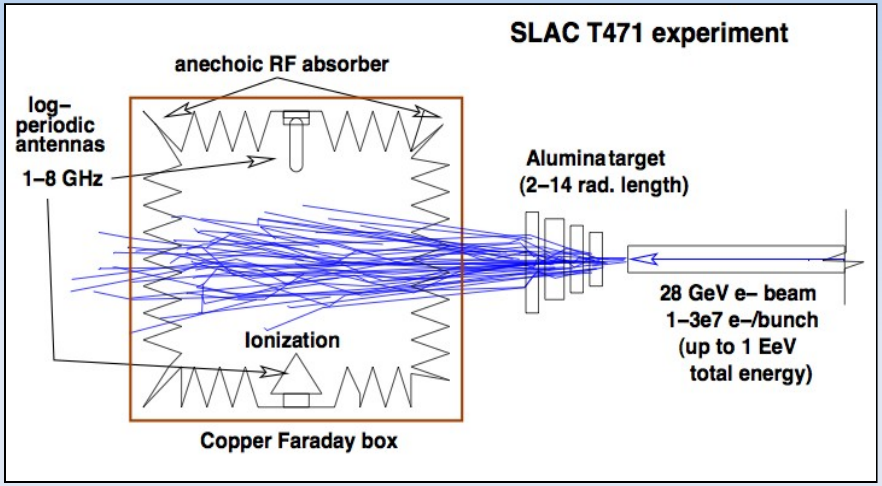
- Recently (in 2008), the observation of a microwave continuum emission from air shower plasmas has raised the interest in a possible new detection technique for ultra-high energy cosmic rays
- The plasma is created after the release of the energy shower in the atmosphere and it is made by electrons with temperature of about 10^5 K
- The plasma cooling process holds over a time scale of a few nanoseconds and it comes mainly via the medium excitation.
- A Microwave Bremsstrahlung Radiation (MBR) is emitted by secondary electrons accelerating in collisions with neutral molecules of the atmosphere.
- The radiation is expected to be isotropic and un-polarized.

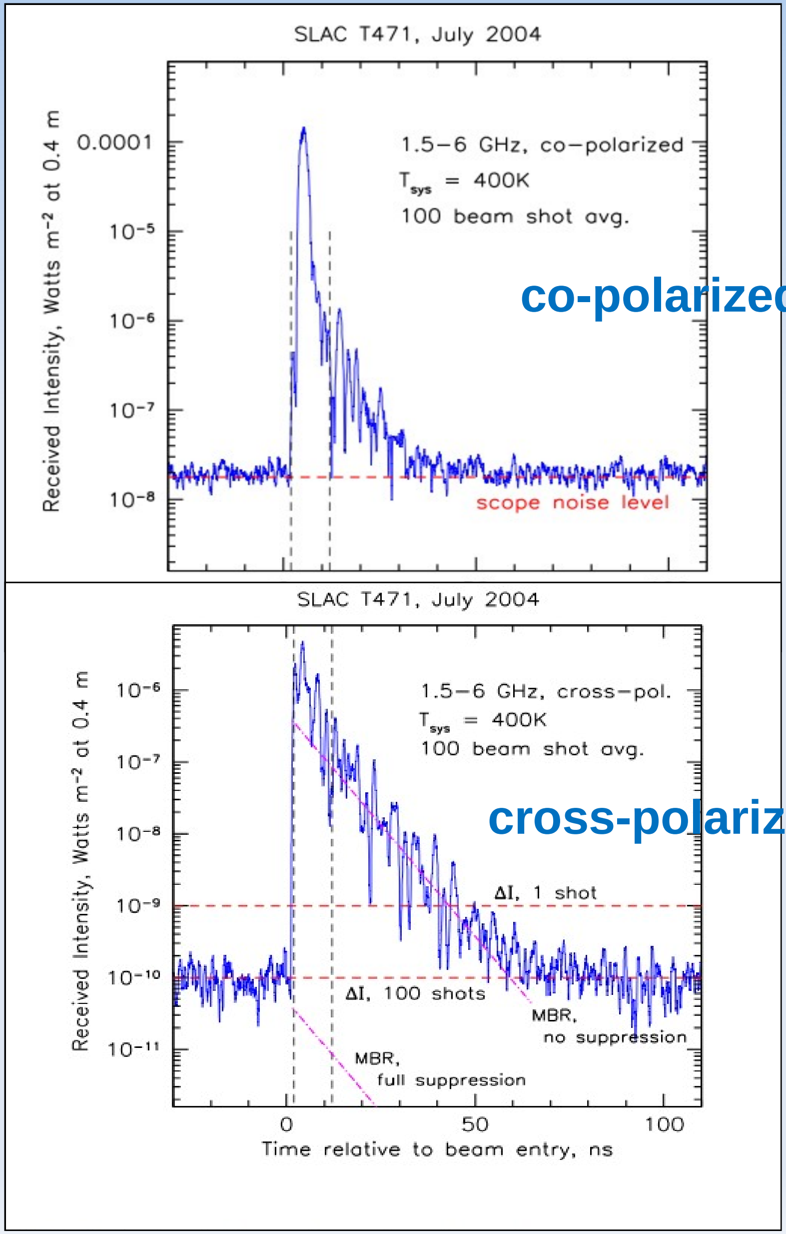
The AMY project aims to measure the MBR absolute yield and its frequency spectrum between 1 and 20 GHz at the Beam Test Facility (BTF) of Frascati INFN National Laboratory. The final purpose is to characterize a process to be used in a next generation detectors of ultra-high energy cosmic rays (10^{20} eV).

SLAC Experiment

P.W. GORHAM ET AL., PHYS. REV. D 78, 032007 (2008)

Experimental apparatus

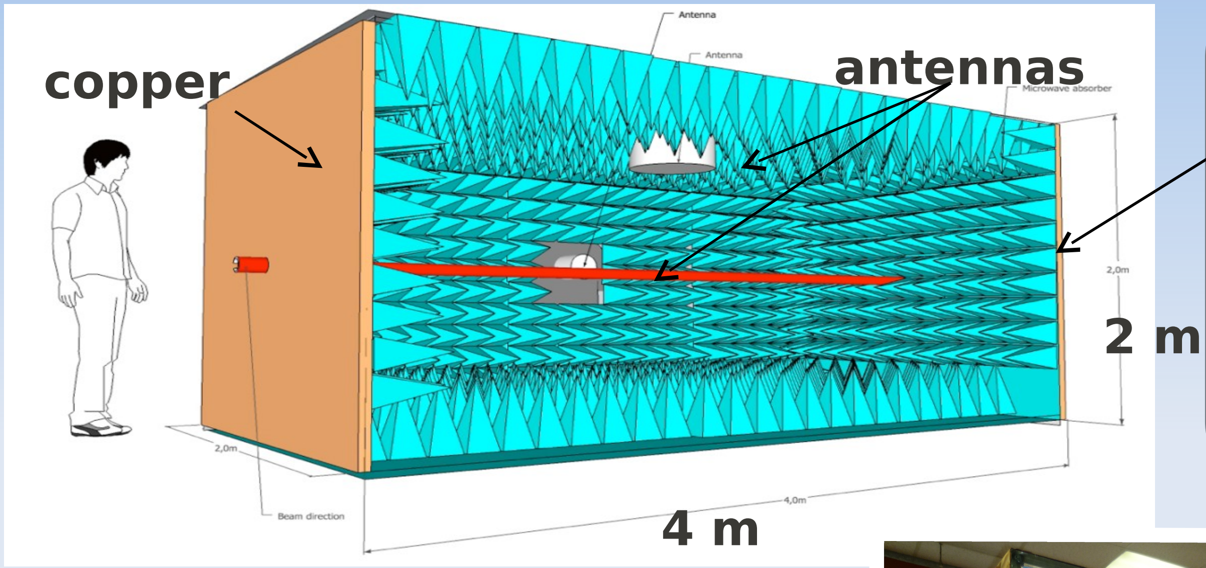


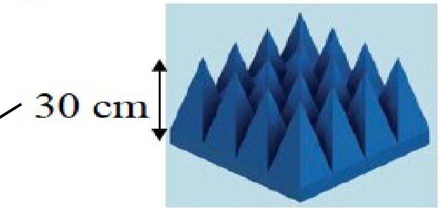


- e-beam on Alumina target
- 2 log- periodic antennas

Intensity vs time shows an exponential decay (15-30 ns)

AMY Experimental apparatus:
The anechoic Faraday chamber

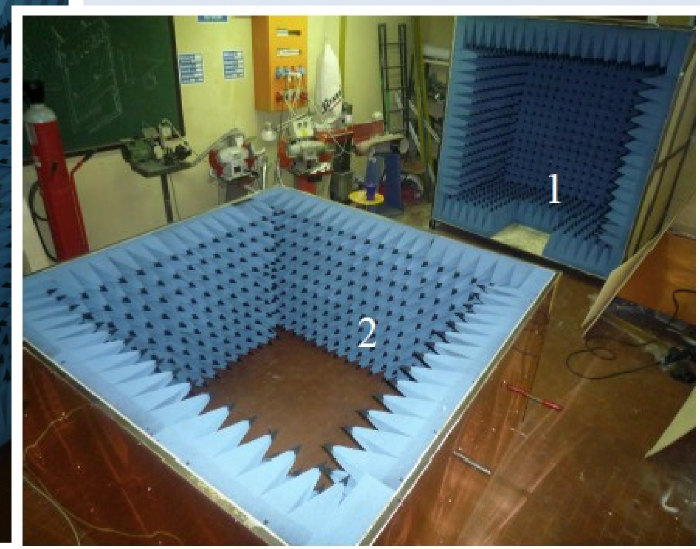




RF ABSORBERS
SATIMO AEP 12
Attenuation:
- 1GHz : 30 dB
- <6GHz: 50 db

Three modules:
- 1-3 length 1,5 m
- 2 length 1 m

Measured shielding for outside radiation above 4 GHz better than 85 dB, it reduces down to 40 dB at 1 GHz.



AMY Experimental apparatus: Instrumentation

(2) HORN DRH20 RFSPIN
•Range: 1.7-20 GHz
• Gain: 6-16 dBi

(2) Log Periodic Rohde&Schwarz HL050
•Range: 0.25-26.5 GHz
•Gain: ~8.5 dBi

Amplifier Mini-Circuit ZVA-183-S+
•800MHz-21GHz
•Gain 26dB

- Oscilloscope LECROY SDA 830Zi-A: 4 ch, 20 GHz real time bandwidth, 40 GS/s
- Spectrum analyzer ROHDE&SCHWARZ SFSV30: 9-30 kHz, 40 MHz bandwidth
- Microwave signal generator ROHDE&SCHWARZ SMF100A: 100 KHz to 22 GHz.

GRAZIE a Dr.Notaro (LeCroy) e ad **Alessandro Corvaglia**

The key point of the measurement

- Above ≈ 20 MeV the electrons in air emit cherenkov radiation

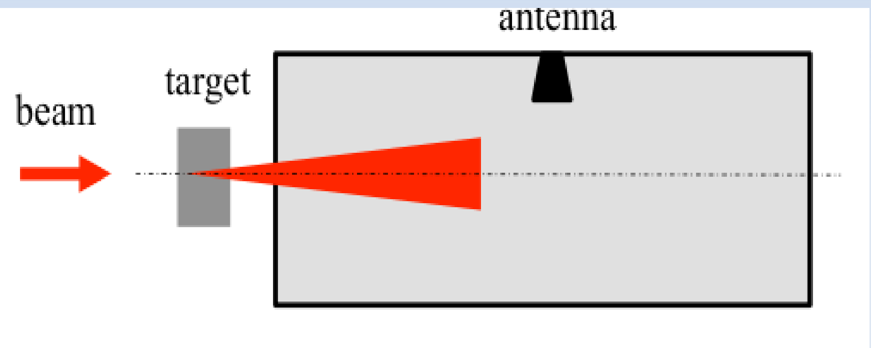
BTF – 510 MeV (SLAC – 28 GeV)

very strong electric field from the beam at the GHz frequencies (bkg)

- MBR should be produced by secondary electrons

maximize the energy deposit

by producing an air shower



- the cherenkov radiation is polarized in the plane defined by the poynting vector and the electron velocity

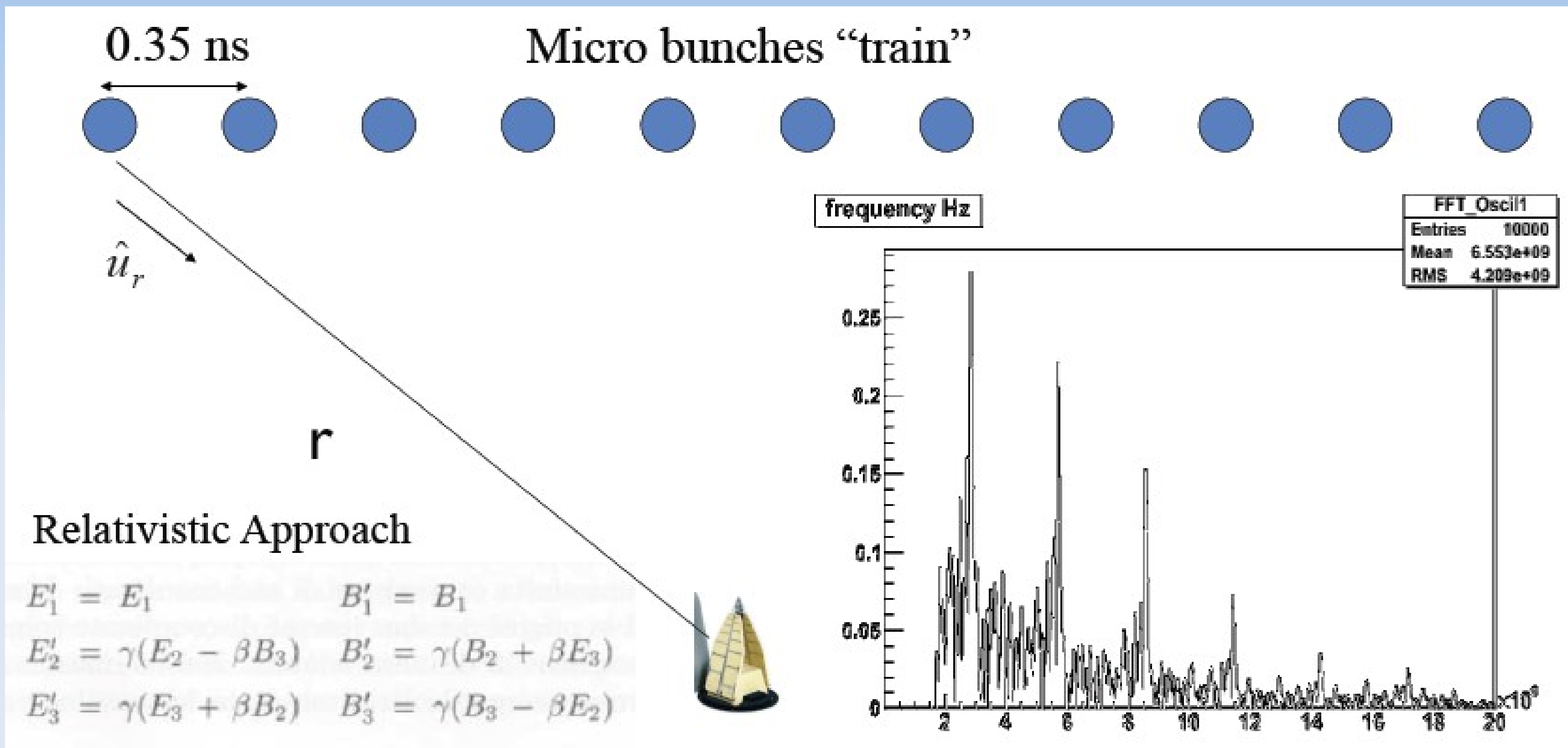
Antenna polarization

orthogonal to this plane (cross-pol.) minimize cherenkov

parallel to this plane (co-pol) maximize cherenkov

as suggested in the P.Gorham et al. paper

SIMULATION



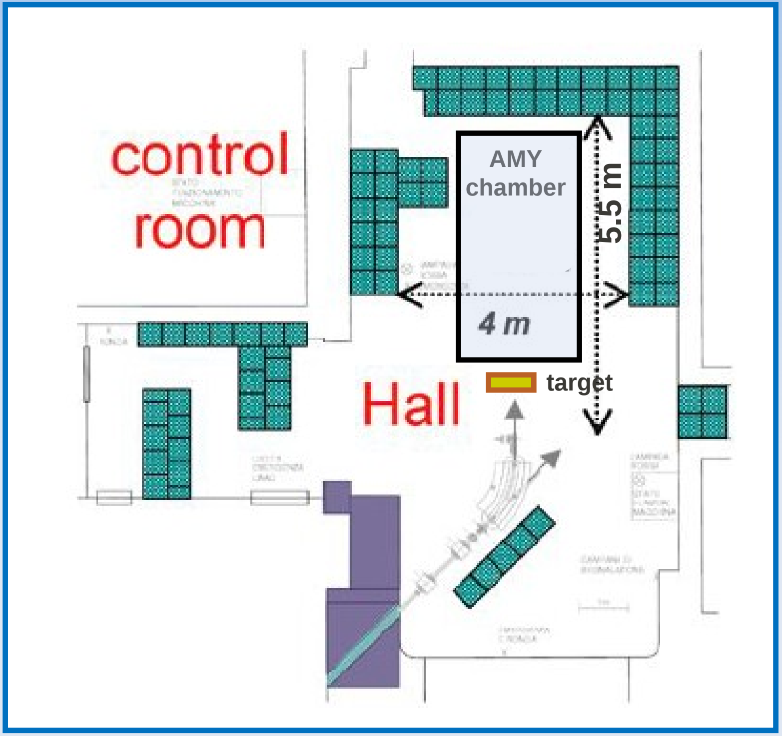
- E and B calculated each 6.6×10^{-13} s in the lab ref. syst.
- The charge are propagated along the beam assuming constant speed and using time step of $6.c\times10^{-13}$ s
- The propagation time of the signal from the bunch to the antenna is take into account

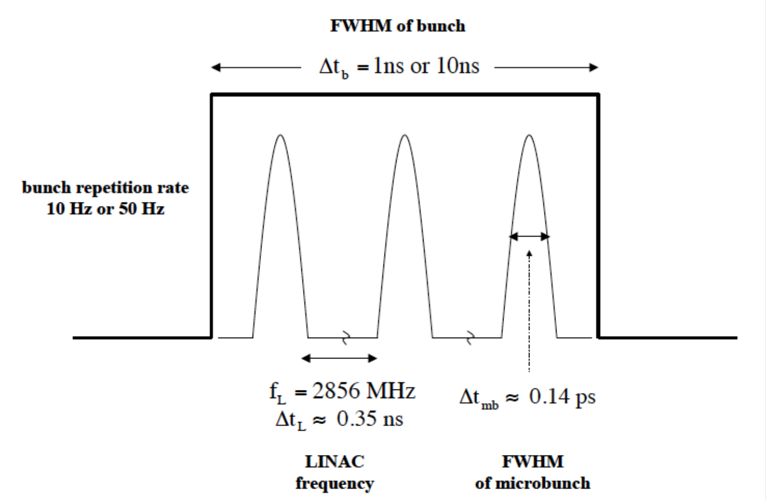
Simulation of the electric and magnetic filed produced by the beam near the antenna

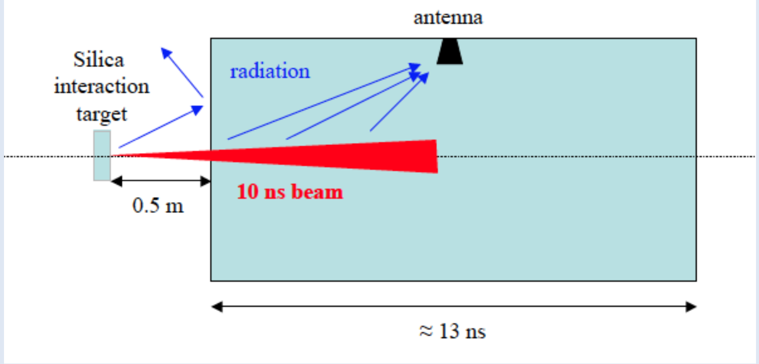
- **Understanding the radiation emitted by the beam**
- **Background for MBR**
- **Benchmark to understand the detector**

First test beam nov21-dec04 2011 at BTF of INFN LNF

e-beam delivered @ BTF
- energy range: 25-750 Mev (510 MeV)
- max. rep. rate : 50 Hz (1 or 2 Hz)
- pulse duration: 1-10 ns (i.e. 30 microbunch)
- particles/bunch: up to 10^{10} ($\sim 10^9$)

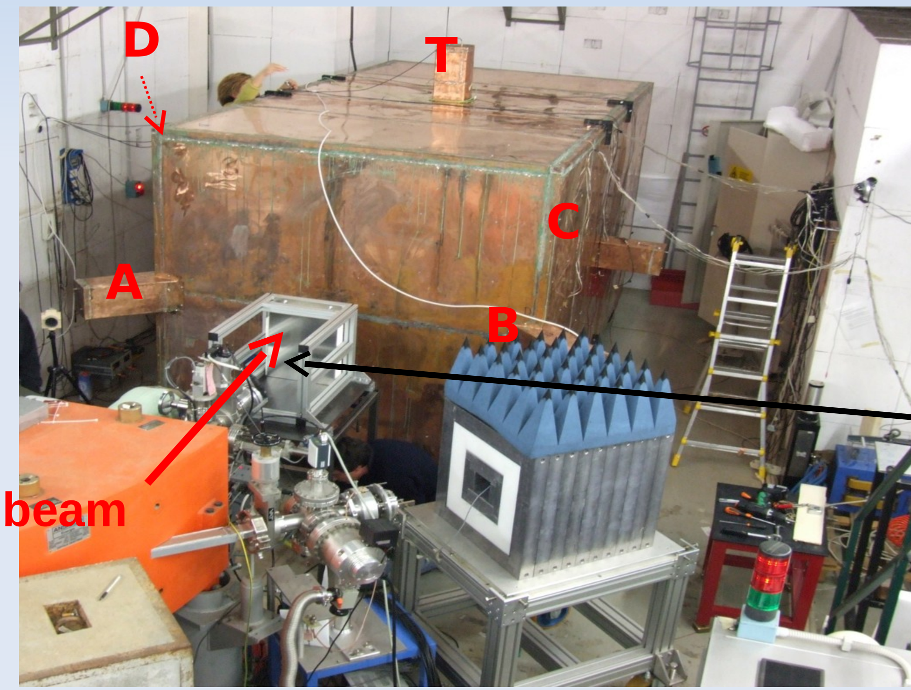


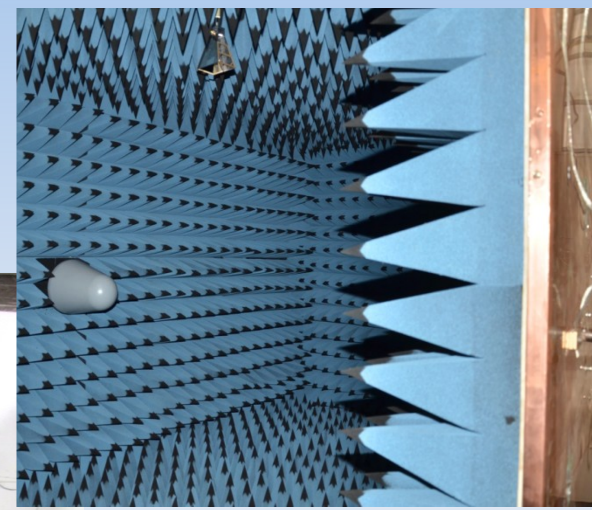


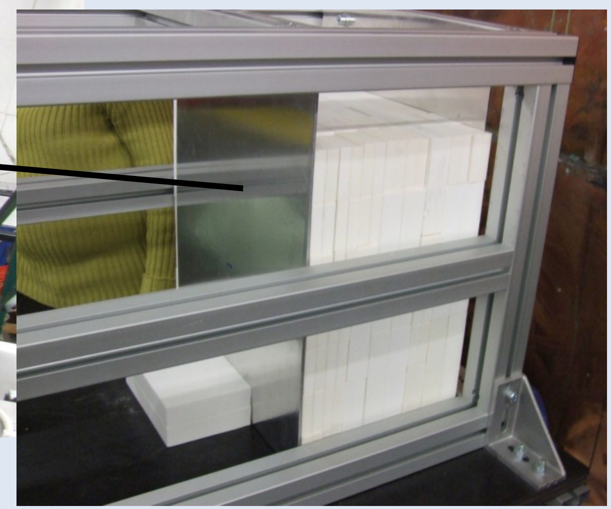


THE BTF AREA @ INFN FRASCATI LAB
ANECHOIC CHAMBER AND TARGET VIEW

5 antennas positions:
- 2 at the corners (A, B)
- 2 on the sides (C, D)
- 1 on the top (T)





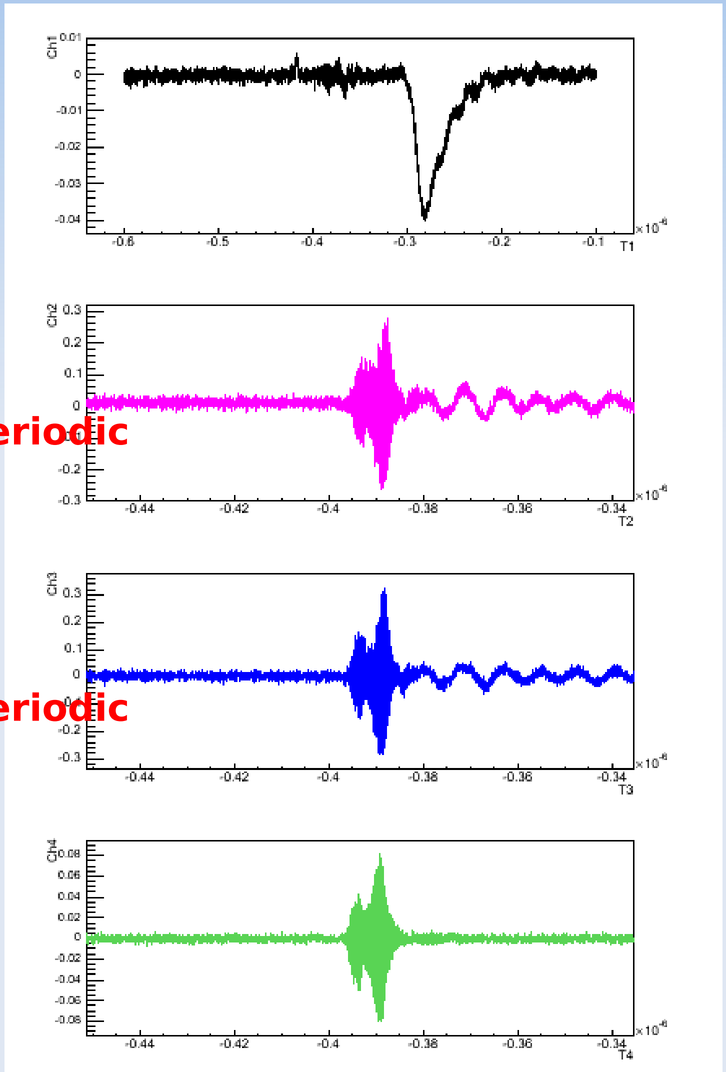


notice:
- only two days of runs with the target
≈ 13000 triggers
problems with the radiation safety rules of LNF
- runs in parallel to the normal DAFNE

20 cm of alumina target (shower maximum in air at 10 cm)

OSCILLOSCOPE SIGNALS

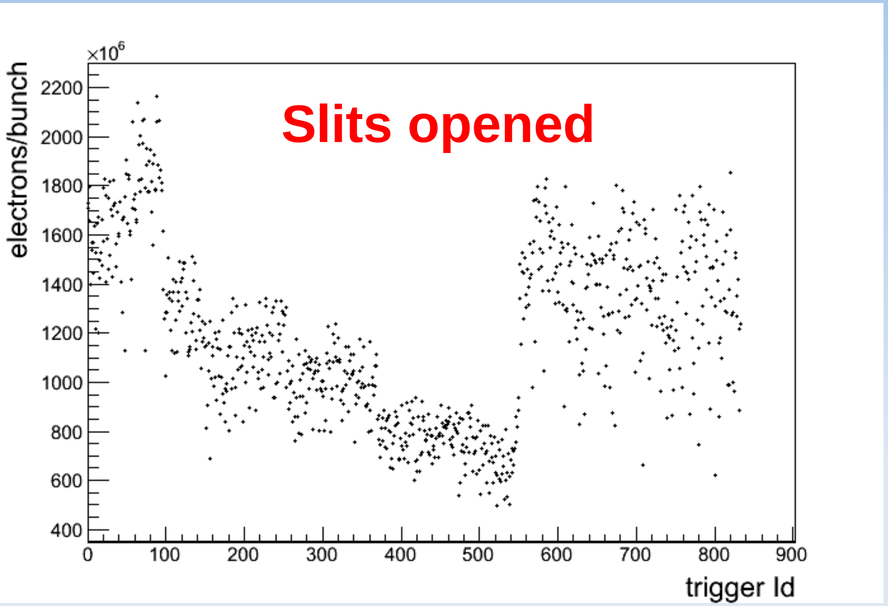
- Run Id: 201112040620
  Event Id: 43160
- about 300 runs
- most of the time e^+-beam
- events/run ≈ 1000
- event trigger with signal from pickup coil

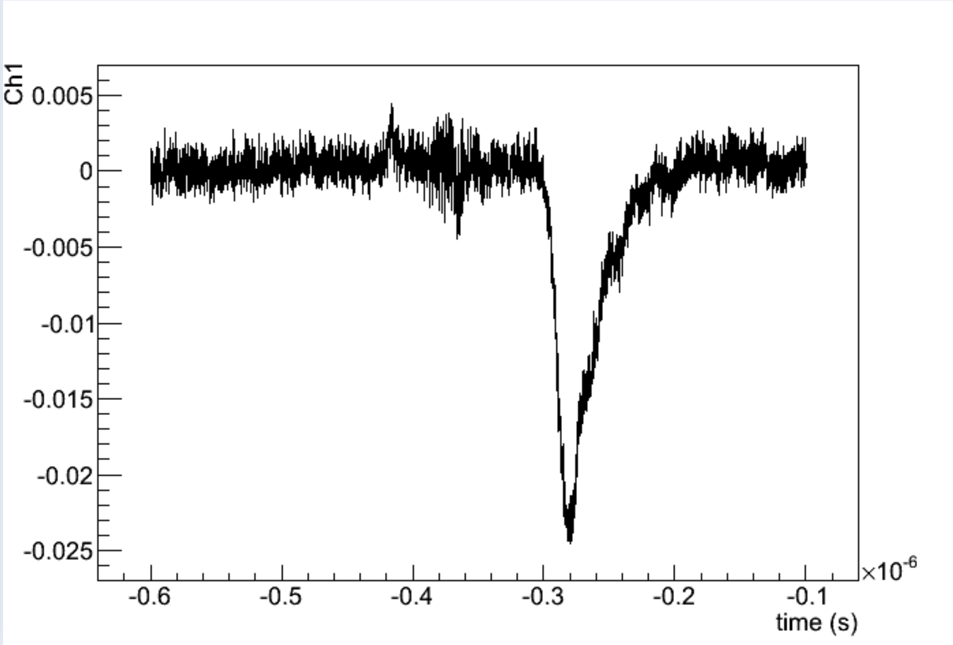


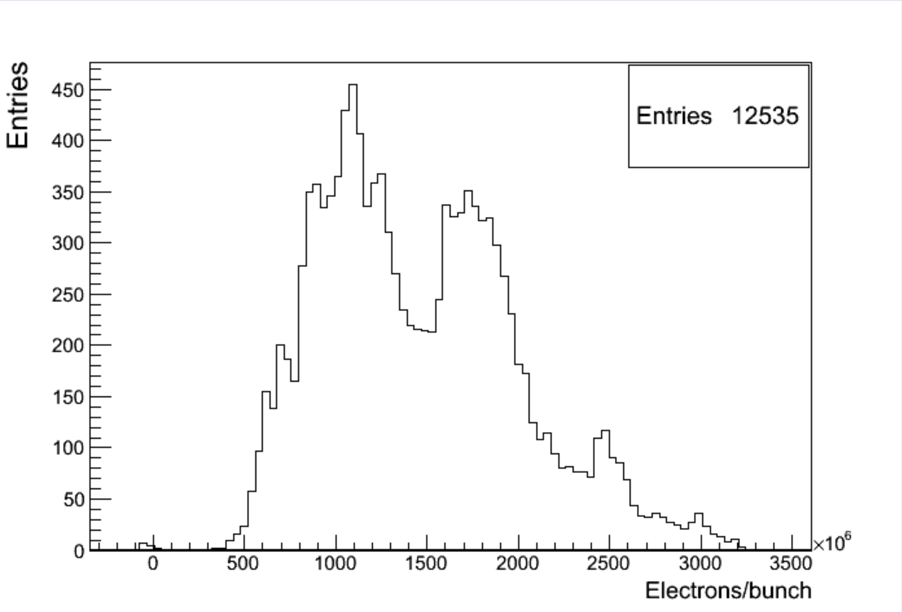
BEAM SIGNAL

Beam signal given by an integrating current transformer pulse integral μ N_e

- Trigger from RF (few ps jitter)
- possibility to change the beam intensity acting remotely
- charge calculation



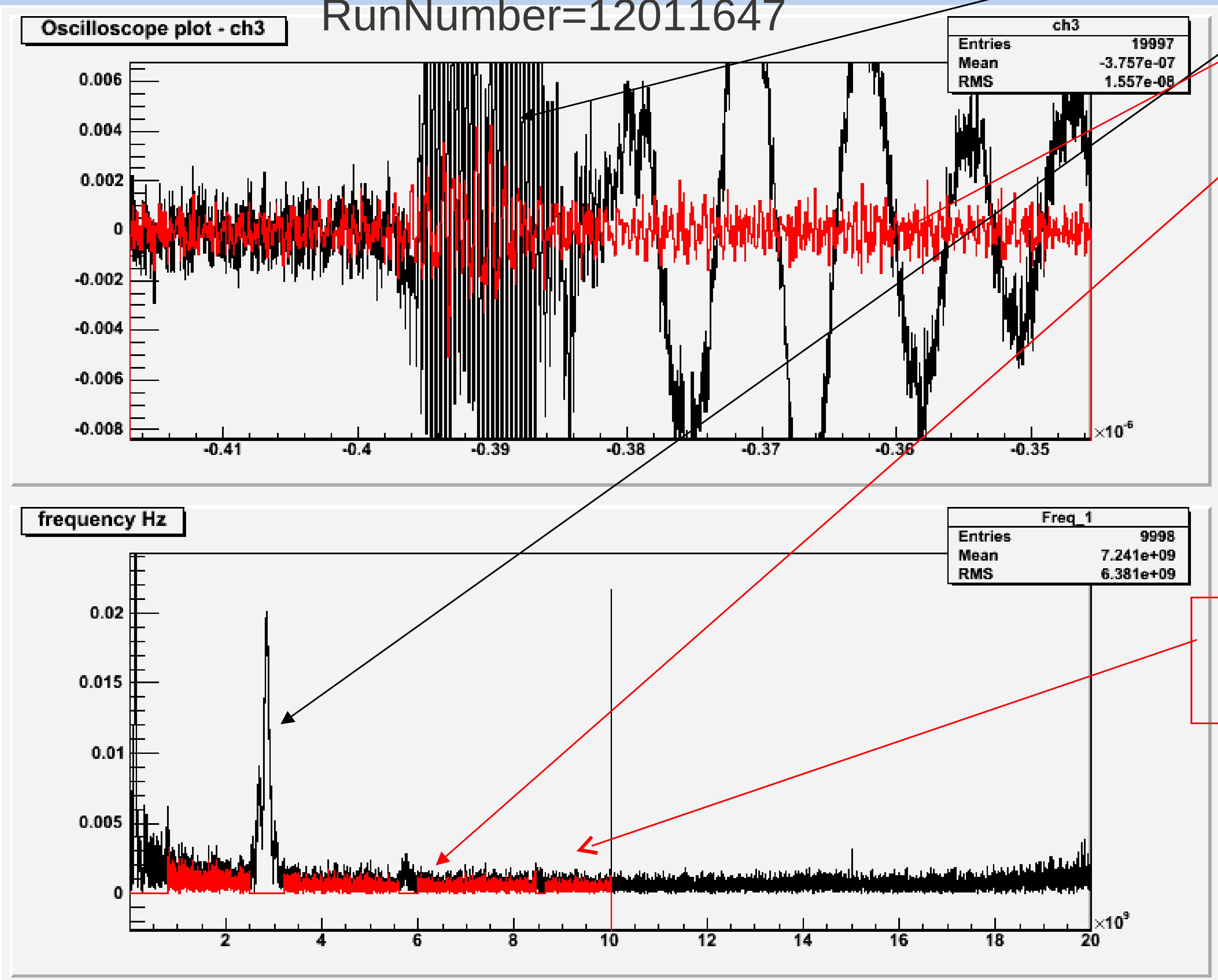




Typical analysis steps

Analysis steps: Signal from Scope
FFT
filter out peaks invFFT
FFT

RunNumber=12011647

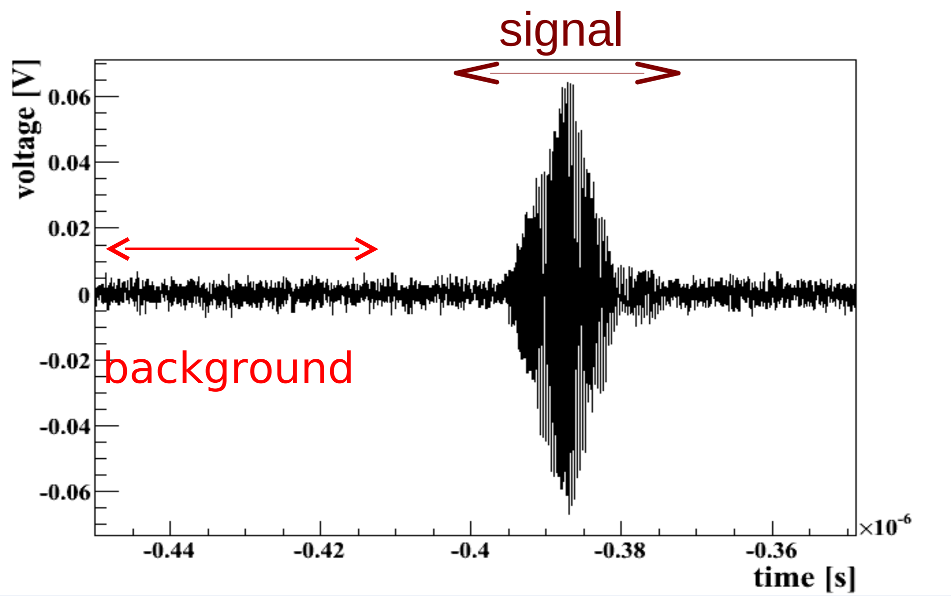


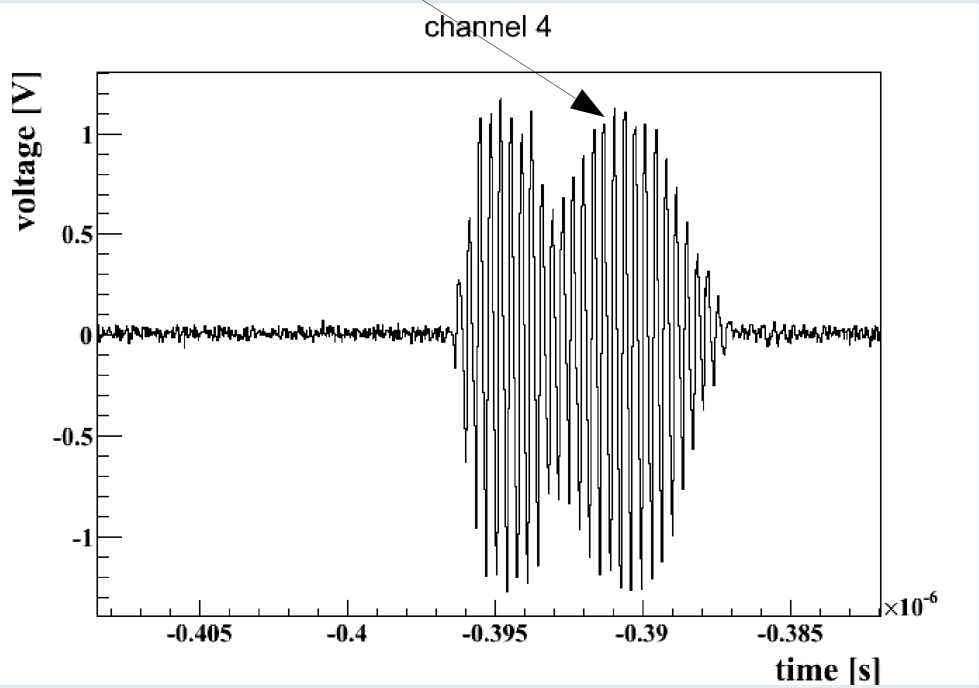
LogPeriodic lateral to the beam copolarized

Note the difference in range of the frequency

ANTENNA SIGNAL
HORN

Range starting from 1.7 GHz
Signal much more clean
Anechoic chamber shield up to 1 GHz around 40 dB
But pattern sometimes very puzzling



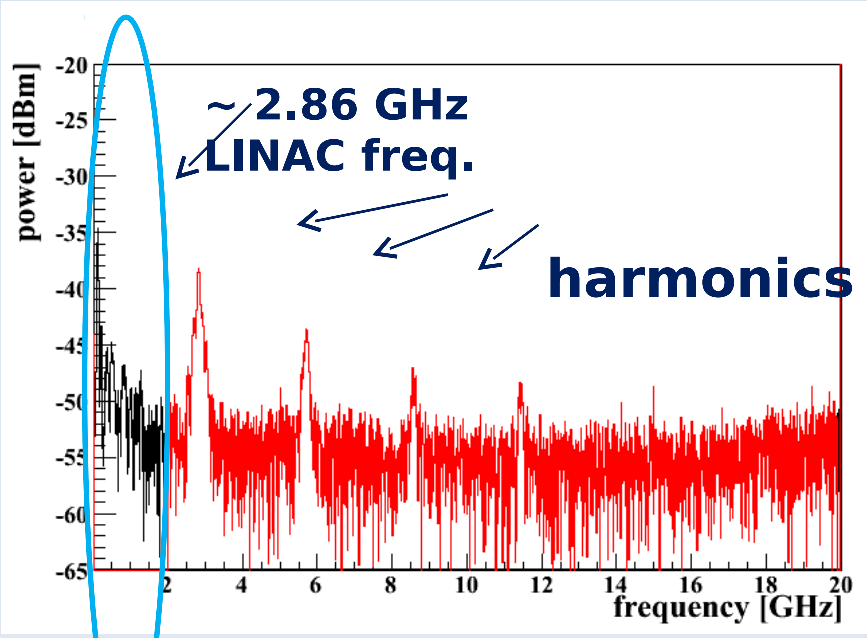


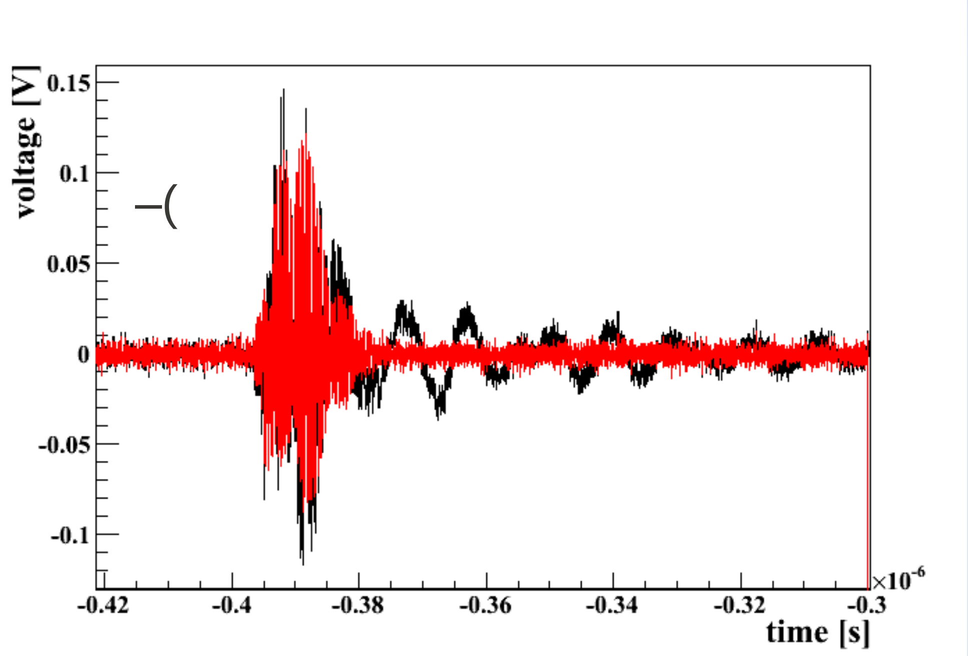
Power Calculation :
Power * 50 Ω = $(Vrms_{sgn})^2 - (Vrms_{bkg})^2$

SPECTRUM ANALYSIS
FFT

FFT of the row signal
FFT of the filtered signal

row signal
filtered signal



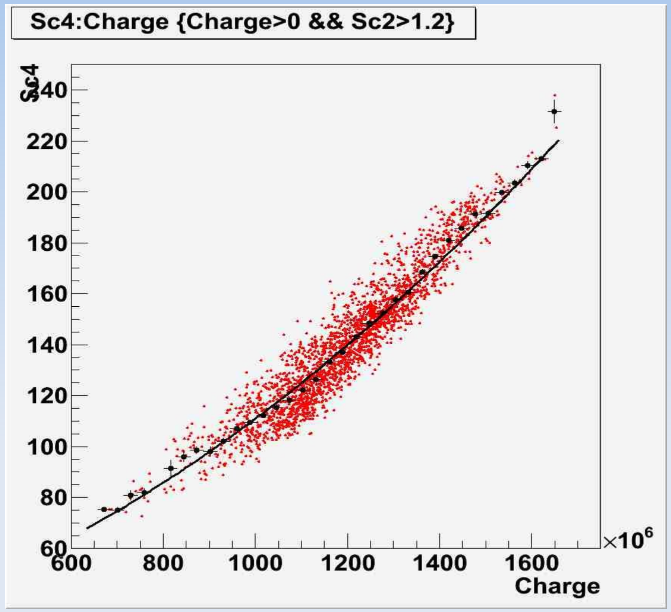


low frequency background
(in log periodic antenna)

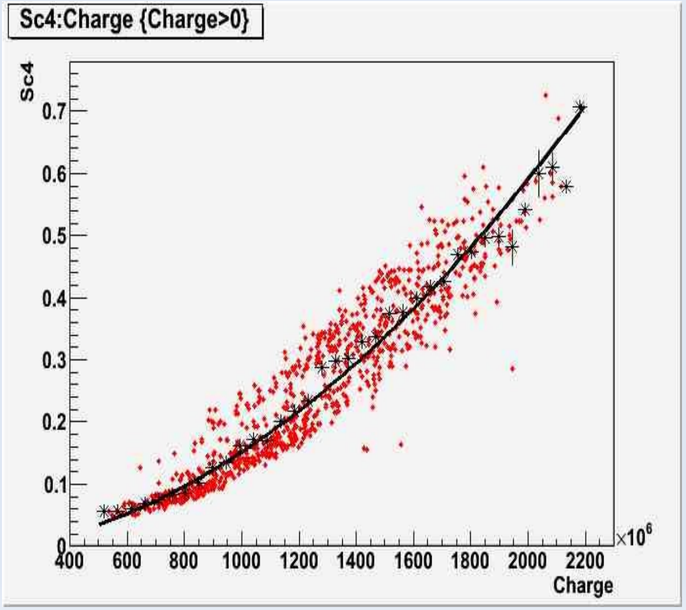
SIGNAL POWER QUADRATIC SCALING

- Power signal shows a quadratic dependence from the beam intensity .
- This trend does not depend on the orientation of the antenna polarization plane.

- Linac peaks included



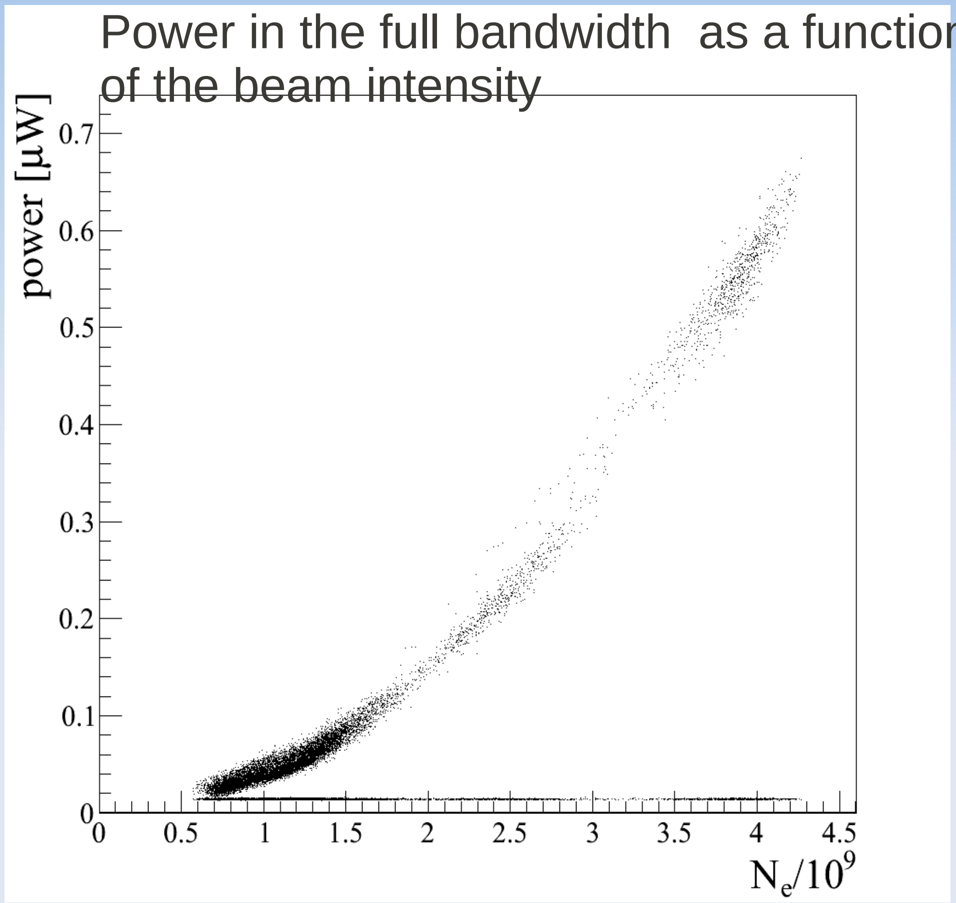
signal Vs Charge for 2600 events in horn Co-polarized looking at the beam
The fit is with a 2nd order Polinomial.

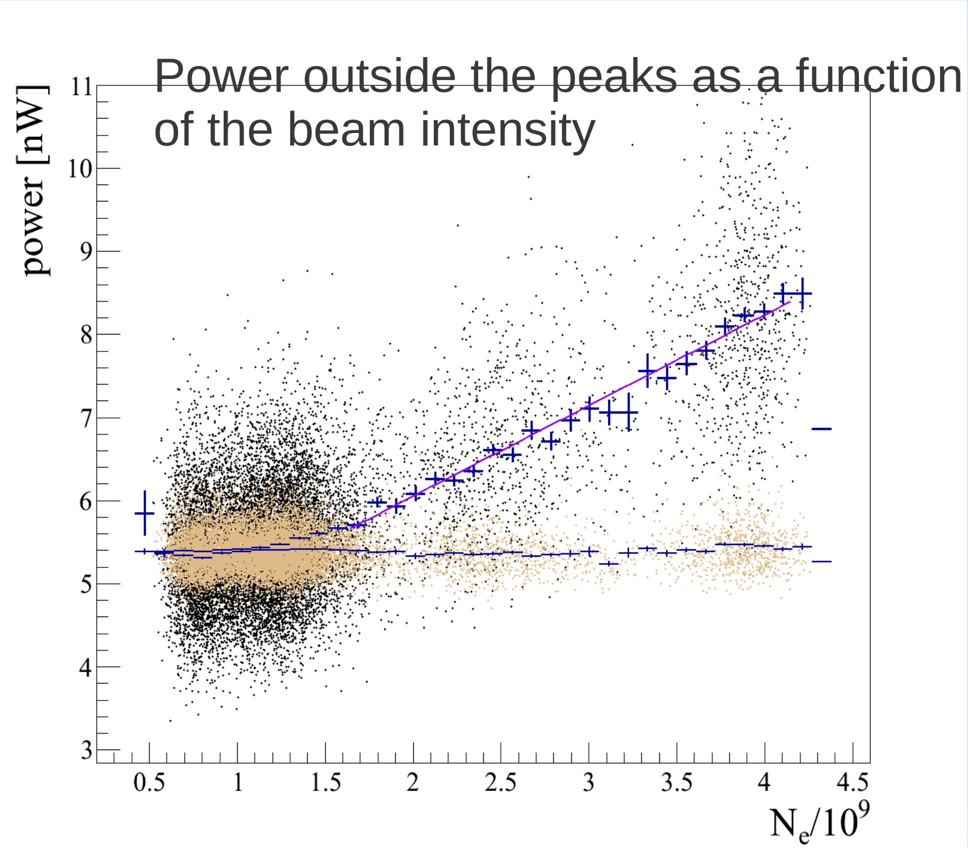


signal Vs Charge for 900 events in horn Cross-polarized looking at the beam
The fit is with a 2nd order Polinomial

SIGNAL POWER QUADRATIC SCALING ?

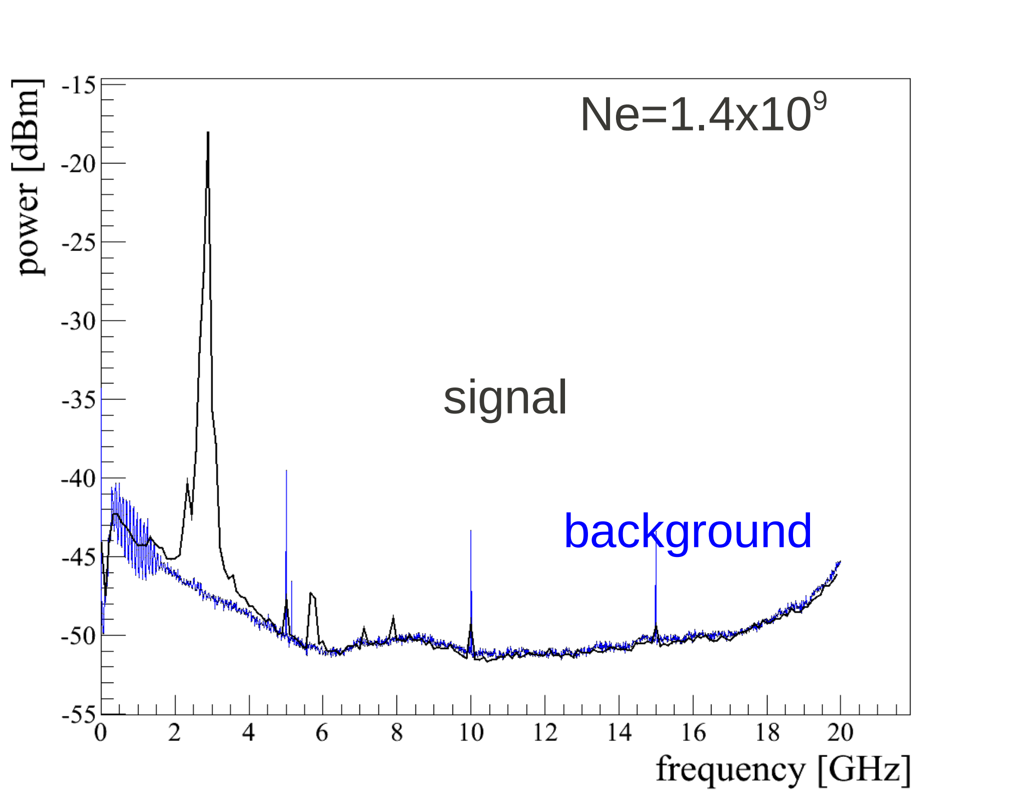
13000 triggers with interaction target

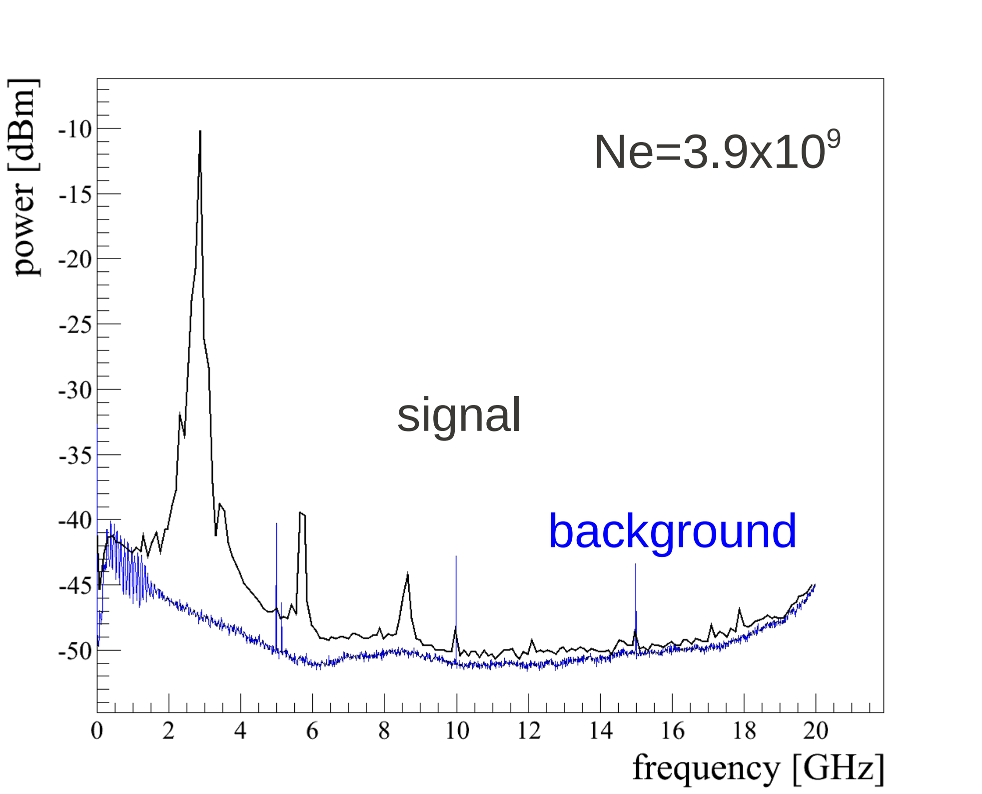




the quadratic scaling observed over the full bandwidth is dominated by the LINAC peaks

Average signal Vs Frequency (frequency spectrum of the FFT scope traces)





The radiation outside the LINAC peaks becomes observable when the current is higher

Second test Beam

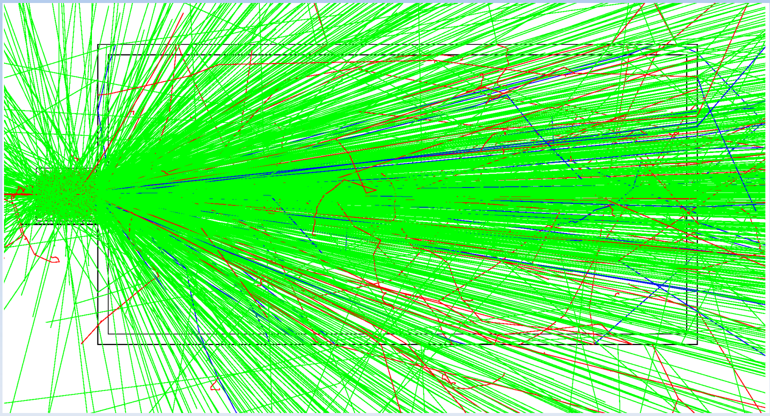
May 14 - 27 (2012)

THE MAIN LIMITATIONS TO OVERCOME HAVE BEEN CLEAR ONLY AFTER THE FIRST TEST BEAM.

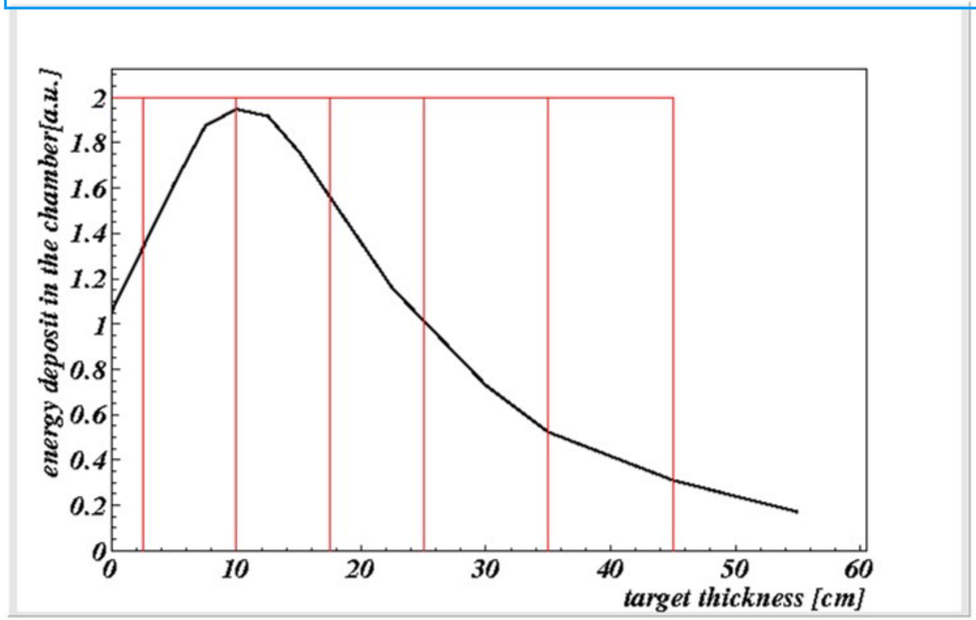
- <u>Remote control of the interaction target</u> **(LECCE)**
- Improve the overall geometrical precision of the camera (antenna positioning and orientation of the polarization plane) **(ROMA2)**
- Increase the beam current by a factor 10 – radiation protection service
- 3 ns bunches

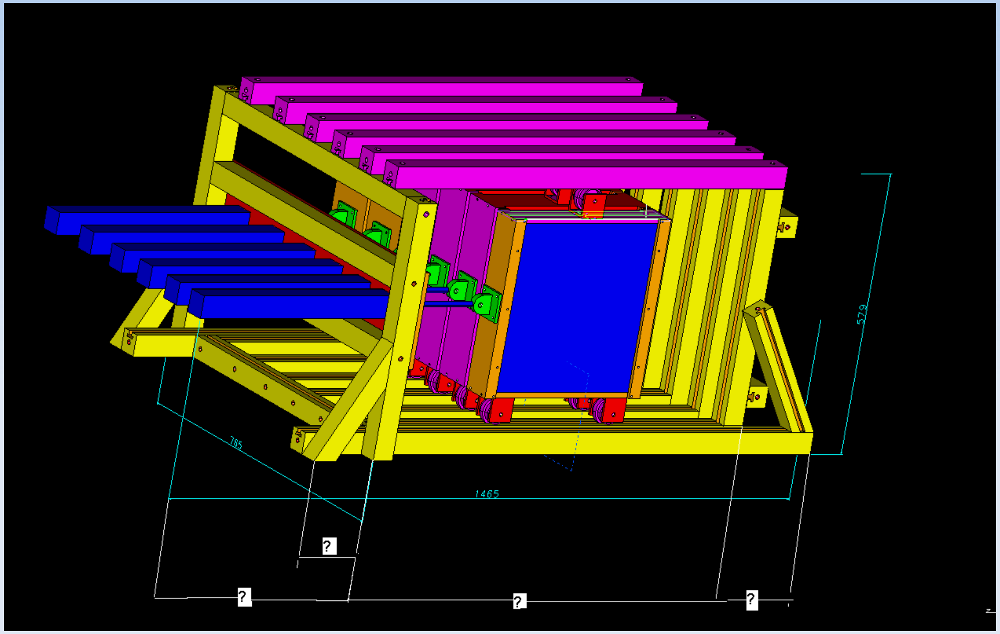
THANKS TO Pino FIORE (Mechanical service)

Remote control of the interaction target (technical design by Pino Fiore, simulation by Dr. Martina Bohacova (stay at Lecce thanks to INFN-FAI)



The shower is fully developed already after passing 10 cm allumina





6 Modules:

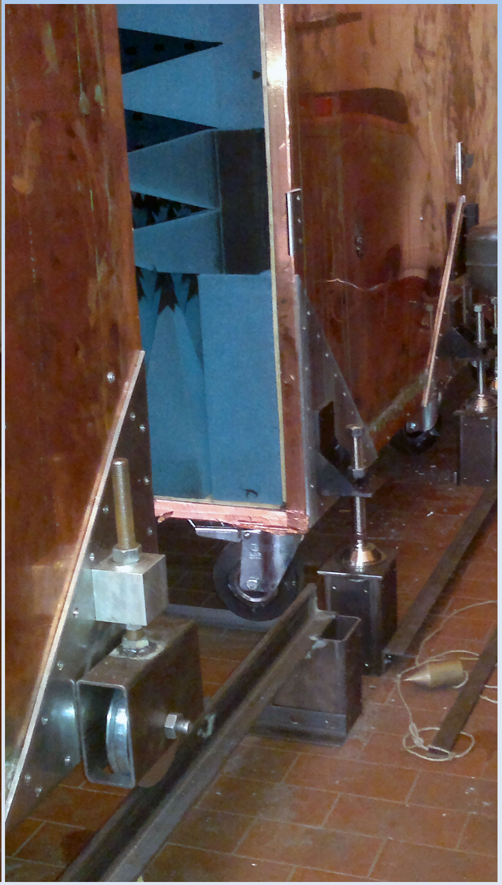
2.5 cm (x35cmx35cm)
7.5 cm
7.5 cm
10.0 cm
10.0 cm

Interaction target in the BTF area
During mounting

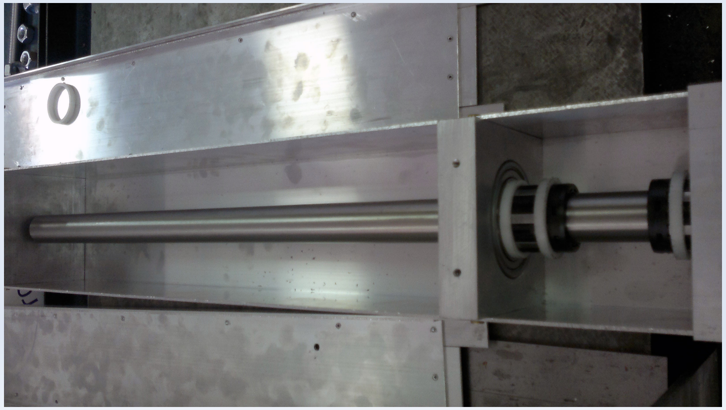
- 6 radiation lengths selectable
- compressed air system

Improve the overall geometrical precision of the camera



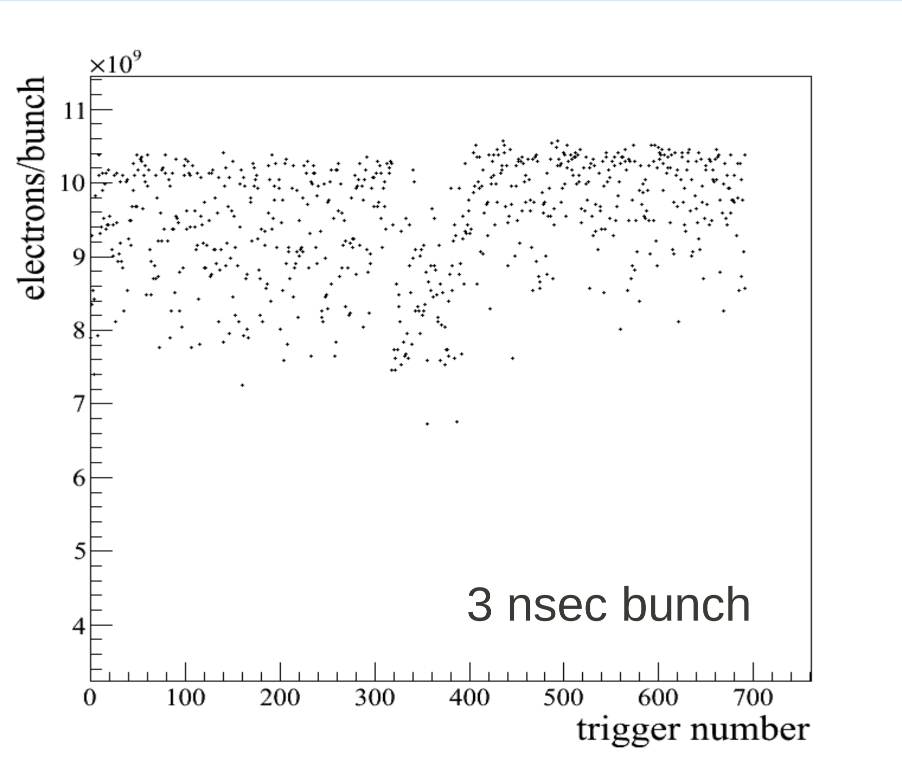


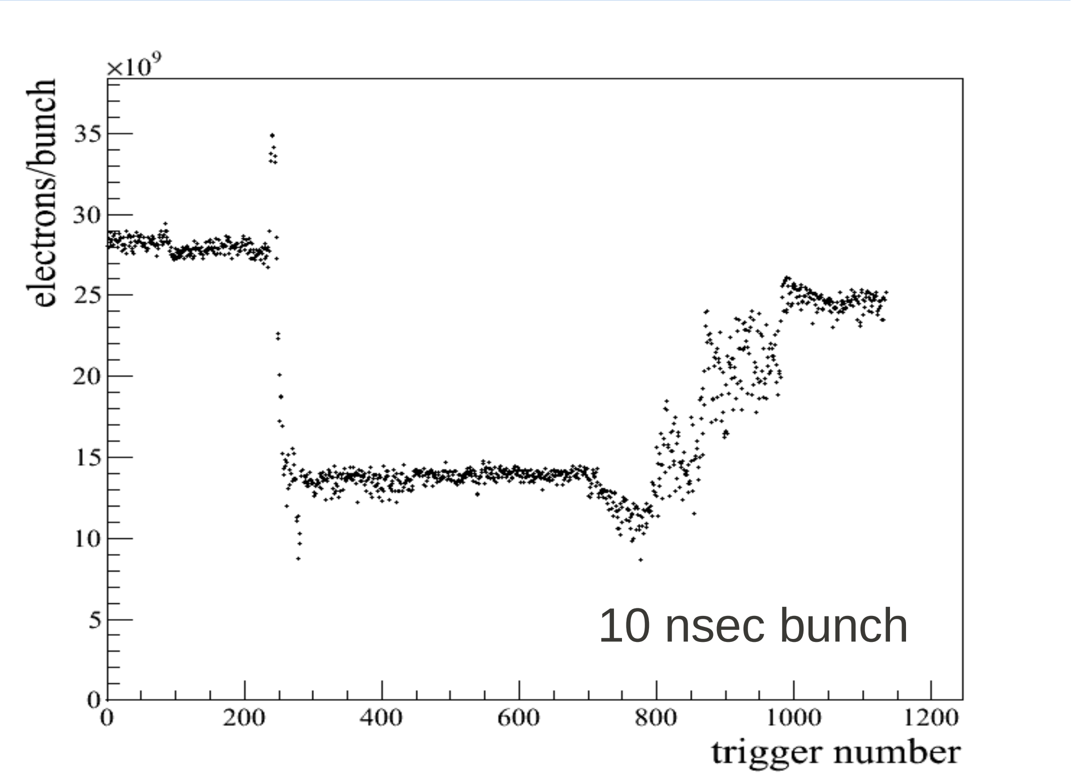
Chamber on rails

Support for a more precise positioning of the antennas

5 days of dedicated runs + Higher intensity + 3ns bunch



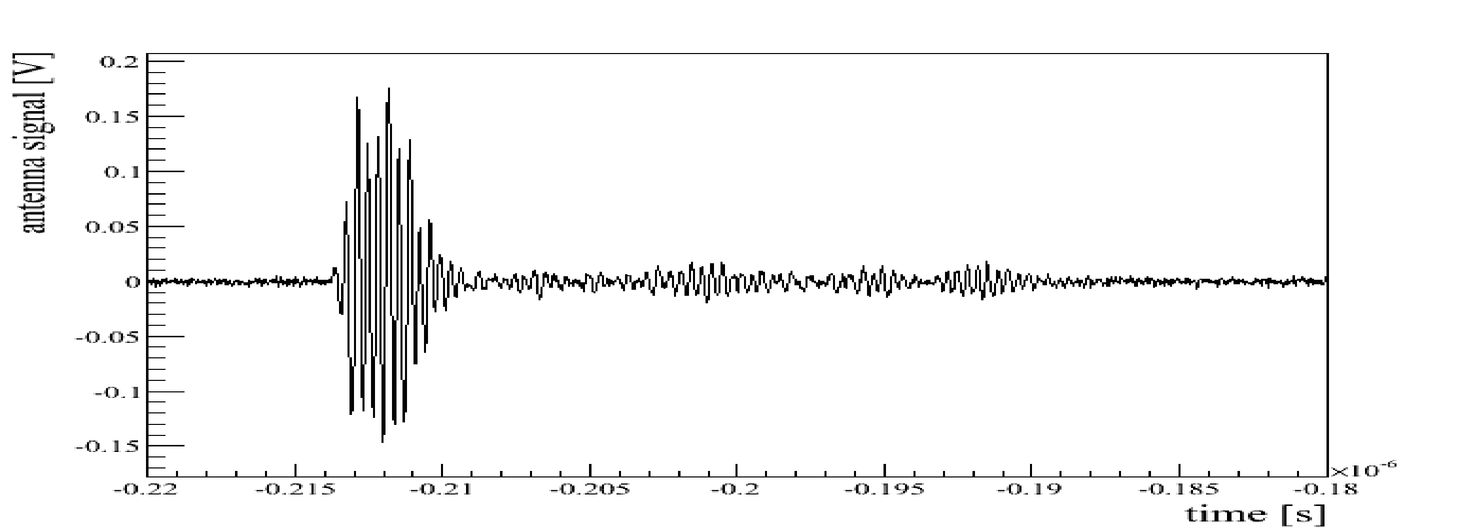


The beam intensity was stably between 10^9 and $5\ 10^9$ electrons/bunch (notice: radiation safety problems at the previous test when running with the target)

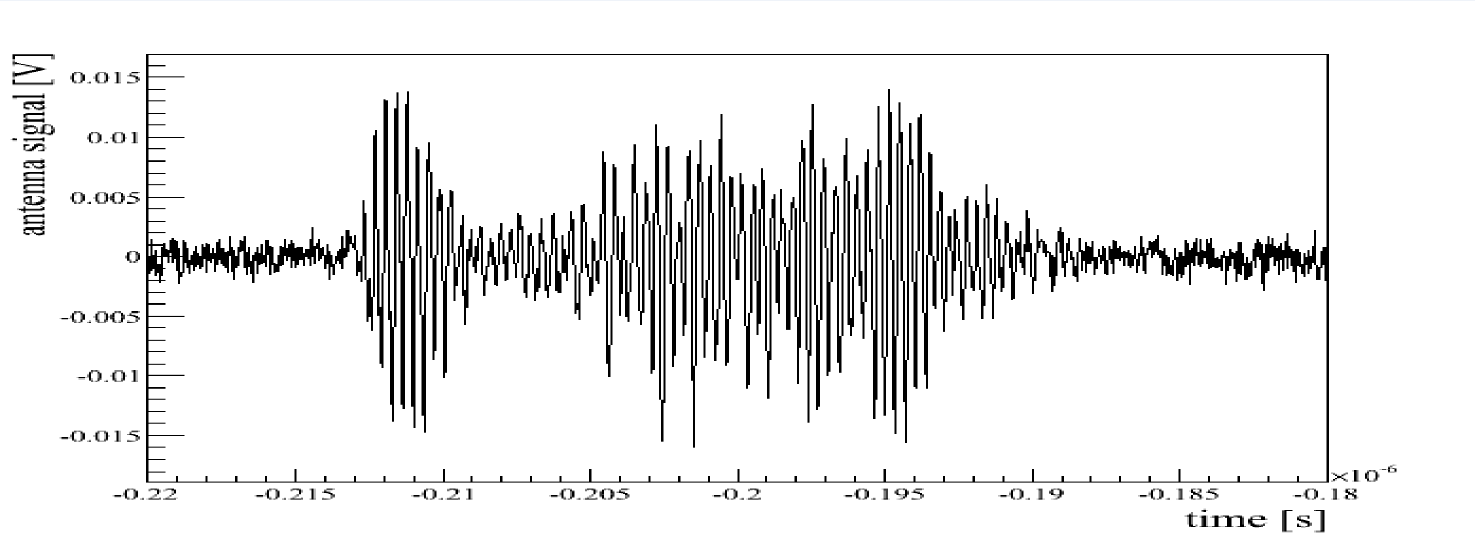
Few runs a factor 10 higher current

Presence of Reflections inside the chamber ?

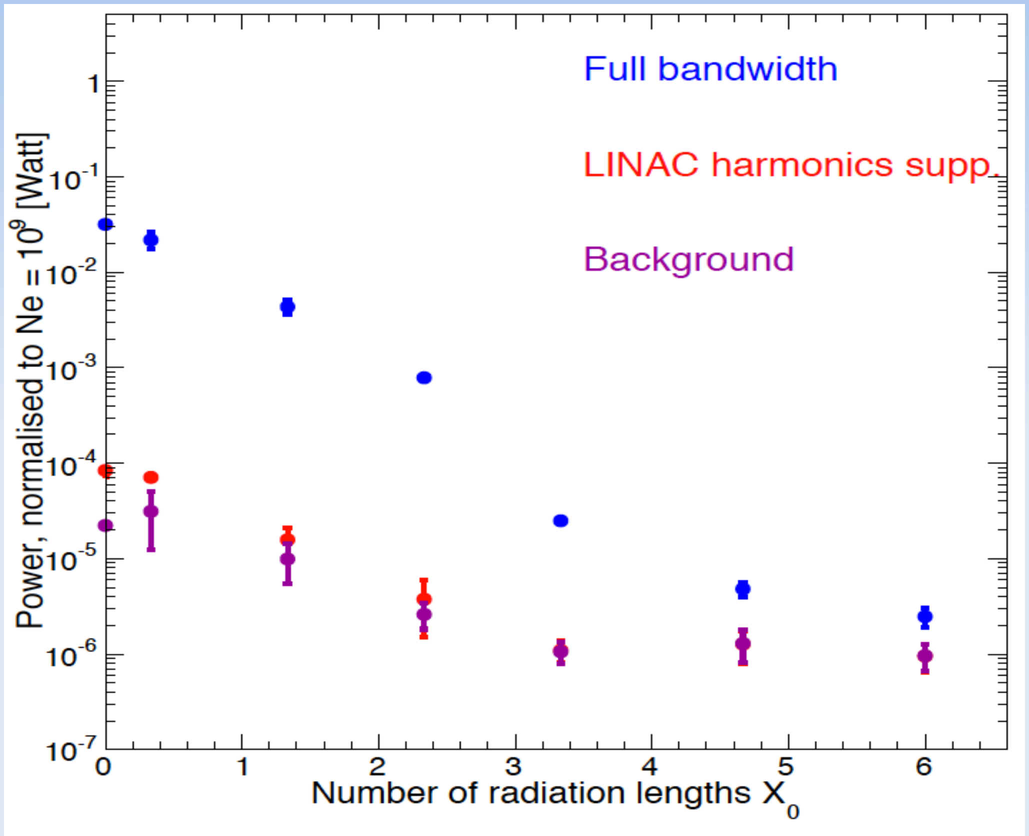
Horn
co-polarized

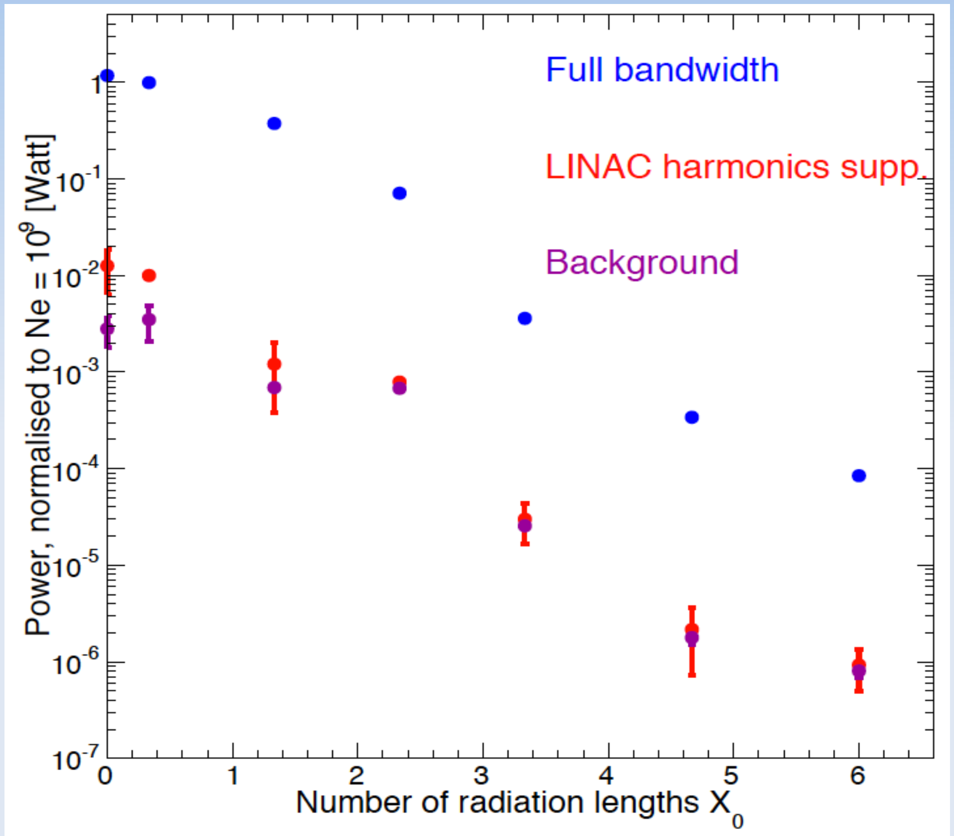


Horn
cross-polarized



Signal Vs Target Tickness (Last test beam)





CONCLUSIONS from a physics view

- Two test beam performed: November 21 – December 4 (2011)
- May 14 - 27 (2012)
- With the second test very close to optimal run conditions (radiations, 3ns, $>10^{10}$, …)
- We should have detected the MBR if it has the intensity reported by P.Gorham et al. Do we have detected it? Difficult to say, analysis and simulation are underwayù
- We have to understand what is the configuration maximizing the sensitivity to MBR (= minimizing Cherenkov)
- Shutdown of DAFNE at the end of the year can give the possibility to make a test with a dedicated beam

CONCLUSIONI

- Proposta di un ulteriore anno probabilmente sotto Dotazioni V per eventuale test beam e per proseguire e concludere l'analisi.
- Le prime presentazioni a conferenza (orali o posters) con ref. articoli
  - da Lecce: M.R. Coluccia (IFAE) presentazione orale
  - G.Cataldi (ECRS2012- next week) poster.
- Percentuali per l'anno prossimo da definire: va specificato che le persone di Lecce che hanno manifestato interesse inizialmente lavorano attivamente al progetto.
- Il contributo extra del servizio di meccanica (Pino) è stato FONDAMENTALE.
- Il contributo extra del servizio di elettronica (Alessandro) è stato FONDAMENTALE.
- Lecce è coinvolta in tutti gli aspetti dell'esperimento (analisi/simulazione/presa dati, costruzione apparato. …)